APOLLO 17
COMBINED 10 DAY COINCIDENCE ANALYSIS DATA
72-096C-09A

APOLLO 17 LM/ASLEP

COMB. 10 DAY COIN. ANA. DATA, TAPE

72-096C-09A

This data set has been restored. There was originally one 7-track, 800 BPI tape written in Binary. There is one restored tape. The DR tape is a 3480 cartridge and the DS tape is 9-track, 6250 BPI. The original tape was created on a 1108 computer and the restored tape was created on an IBM 9021 computer. The DR and DS numbers along with the corresponding D number are as follows:

DR#	DS#	D#	FILES
DR005906	DS005906	D031943	1 - 32

REQ. AGENT	REQ. NO.	ACQ. AGENT
CMP LSM	RD0813	RWV

APOLLO 17

COMBINED 10 DAY COINCIDENCE ANALYSIS DATA

72-096C-09A

THIS DATA SET CATALOG CONSISTS OF 1 TAPE. THE TAPE IS 9 TRACK, 800 BPI, BINARY WITH 32 FILES OF DATA. THE TAPE WAS CREATED ON AN UNIVAC 1108 COMPUTER. THE DATA CONTAINS NO TIME SPANS. FOR FURTHER DOCUMENTATION SEE DOCUMENT B#34870-000A. BELOW ARE THE D AND C NUMBERS:

D#	C#
D-31943	C-23103

UNIVERSITY OF MARYLAND
COLLEGE PARK, MARYLAND 20742

DEPARTMENT OF PHYSICS AND ASTRONOMY
301-454-3401

Division of Mathematical and Physical
Sciences and Engineering

August 1, 1978

National Space Science Data Center
Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland 20771

Attn: Mr. Ralph Post, Code 601

Gentlemen:

Under separate cover we have sent you our tape #P1025. This tape contains the source tables used to produce the histograms in Appendix B and Appendix C in my technical report The Lunar Surface Gravimeter and the Search for Gravitational Radiation (University of Maryland, Department of Physics and Astronomy Technical Report #78-086) to be published. This publication is already available in the form of my Ph.D. dissertation submitted in May 1978, from University microfilms. There are two sets of coincidence delays; one for Argonne vs. LSG and the other for Maryland vs. LSG. For each star level, a table gives the number of coincidences for each delay time for positive and negative delays as described on page 41 and on pages 37-39 of the mentioned work.

This data is provided for further statistical analysis that researchers may wish to perform on the histograms.

Sincerely yours,

Russell L. Tobias

Russell L. Tobias
Research Assistant

RT:mm

+3579

ABSTRACT

Title of Dissertation: Lunar Surface Gravimeter and the Search for Gravitational Radiation

Russell L. Tobias, Doctor of Philosophy, 1978

Dissertation directed by: Joseph Weber, Ph.D., Professor
Department of Physics and Astronomy

Abstract: A search for gravitational radiation predicted by Einstein's general theory of relativity was made, using the Moon as an instrumented antenna. Data were analyzed from the Lunar Surface Gravimeter Experiment (LSG), part of the Apollo Lunar Surface Experiments Package (ALSEP) deployed on the Moon. It was a component of the United States of America's Apollo 17 manned space flight mission in December, 1972. The LSG can observe accelerations of the lunar surface in the frequency range from approximately 0 to 16 hertz with a nominal sensitivity of approximately a few parts in 10^9 of lunar gravity. A secondary objective of the LSG was to measure the tidal effects on the Moon and to serve as a one axis seismometer.

A calculation of the sensitivity of gravitational radiation detectors enables computation of upper limits of the incident flux for the frequency regions searched. These included the millihertz region, where a search for excitation of the fundamental free modes of the Moon established an upper limit of 1.4×10^{13} ergs/(cm^2 - sec) for continuous gravitational radiation; and the 1 hertz region, where an exploration of higher order free mode excitations set a maximum flux of 5.7×10^{12} ergs/(cm^2 - sec).

Also described is an experiment to search for pulsed radiation with frequency components in the 1 hertz region. Seismic data from the LSG is converted into a form suitable for performing a coincidence analysis with two of the gravitational radiation detectors at Argonne National Laboratory near Chicago, and the University of Maryland in College Park, Maryland. Continuous lunar seismic data in the time period December 15-25, 1973 was converted into the format of the absolute value of the time derivative of the power. It was then processed using existing programs in coincidence with the square of the derivative of the power data from the terrestial detectors. The upper limit on the gravitational radiation energy flux for a pulse was computed to be 3.4×10^{12} ergs/cm^2.

A large number of lunar seismic events were observed, with a sensitivity of a few Angstroms displacement in the .1 to 10 hertz region, and of about .01 Angstroms in a narrow band near 1.5 hertz. No evidence of excitation of the lunar free modes of oscillation or of pulsar radiation was obtained, nor was any useful tidal information acquired. In the coincidence analysis, correlations were noted for displacements occurring on the Moon's surface 5.9 and 6.2 seconds after displacements occurring on the detector at Argonne. The correlation between the displacements is calculated to be as high as 4.43 times the calculated standard deviation of the correlation. The probability of the correlations being of statistical origin is in the order of 2.5 percent, indicating the need for further study. Similar results are not obtained with the Maryland detector.

A3

Included is a brief introduction to the basic theory of gravitational radiation, prospective sources, and methods of detection. Details of the construction and chronology of the LSG are described, along with the algorithms for data processing. A history of the use of the Earth and the Moon as detectors of gravitational radiation is recounted, along with a review of the relevant literature. Comparisons are made between the Earth and the Moon as gravitational radiation detectors.

CHRONOLOGY OF THE EXPERIMENT

The LSG experiment was deployed on December 12, 1972 by the Apollo 17 astronauts. The set-up procedure was to null the sensor beam by adding weights by means of a caging mechanism. However, even with both of the available masses added to the sensor beam assembly, it was not possible to balance it in the proper equilibrium position. The only time the beam moved was when the caging mechanism was in physical contact with it.

To determine if the movement of the beam was being obstructed, the Lunar Module Pilot rapped the exposed top plate on the gimbal; rocked the apparatus in several directions, releveled the instrument; and rechecked the tilt of the sunshade in an attempt to free the sensor beam. However, none of these actions produced any change in the operation of the instrument.

It was then determined that an error in arithmetic made by La Coste and Romberg, the manufacturer of the sensor beam, had not been corrected by the firm. This led to an instrument which had excellent performance in earth g and was just barely outside of the tolerances for variations of lunar site g. This error resulted in the mass of the counterweights being about two percent less than was necessary for operation in the Moon's 1/6-g gravitational field. Unfortunately, the procedure of adding the weights allowed only for up to plus or minus 1.5 percent for possible inaccuracies.

Therefore, it was necessary to balance the beam using a very small force applied by the mass adding mechanism. However, this changed the frequency response of the sensor to a significantly higher frequency than that originally intended. However, the balanced beam system had a much higher quality factor--about 25--instead of being critically damped. This led to much greater sensitivity than the intended design near the resonance and poor sensitivity at very low frequencies. The system was left in open loop (integrator shorted) mode.

After 45 days, no seismic signal was detected, and it was found that the sensor had deviated sufficiently from its proper equilibrium position to saturate the final amplifier. The beam was again centered, and the output observed during a terminator crossing (lunar sunrise or sunset), when rapidly changing temperatures would be expected to produce enough stresses on the Lunar surface to produce detectable seismic activity. Comparison with the Lunar Seismic Profile Experiment (LPSE) verified that the LSG was indeed detecting information from local seismic activity.

On April 19, 1973, the natural resonant frequency was successfully lowered to approximately 2.2 hz, with a displacement sensitivity of 3.5 angstroms. The experiment was left in open loop to obtain some long term results before further experiments were attempted.

On September 26, the experiment was configured for the first time in closed loop operation, in order to detect tidal data. This also reduced the possibility of saturation, so the seismic gain was again returned to maximum. The spring constant and the beam assembly frequency response were measured.

In an attempt to further reduce the instrument's resonant frequency, another reconfiguration was performed on November 30 to better center the sensor beam with the mass caging mechanism. As a result, the natural frequency was lowered to approximately 1.5 hz., and there was noticeable improvement in the free mode channel response. The tidal output was following its predicted pattern with an unexplained distortion in the high frequency region. Unfortunately, the tidal signal later began to show a constant reading at its minimum value, indicating a hardware failure in the tidal channel. No explanation could be found for the problem, and the experiment was left on December 7 in open loop mode with maximum seismic output.

The experiment continued to gather useful data until March 15, 1974, when the heating mechanism began to malfunction, making it impossible to accurately maintain the stabilized operating temperature necessary for useful data acquisition. However, the heating system regained normal operation on April 20.

Most of the data processing had been performed on the University of Maryland's Univac 1108 computer system. No large scale data reduction could be performed within the limits of the experiment's budget, because the 1108 computing costs were about $500 per day's data. A Digital Equipment Corporation PDP-11/40 computer system was acquired to decommutate the data from the source tapes, and for subsequent data analysis.

Financial support for the project came to an end on December 31, 1974. A greatly reduced scale of data analysis was continued using the PDP computer until its return was required by NASA on May 15, 1976, after which some work was continued on a facility owned by the Department of Electrical Engineering. On June 30, 1977, the gravimeter was shut down along with the other ALSEP experiments owing to deterioration of the power generator and other demands on the tracking network.

METHODS OF DATA ANALYSIS

Data from the experiment were sent by telemetry from the ALSEP central station to one of several tracking stations on the Earth. Each tracking station would record the data from all of the ALSEP experiments onto an analogue range tape, which was then sent to a central processing center in Houston, Texas, where a digital tape was prepared containing sixteen thirty-six word logical records.

Each logical record provided in packed format thirty-one seismic channel voltage readings separated by .01887 seconds (except for the first reading in each record which was omitted to allow for synchronization information). Also included was one free modes channel reading, and one tidal (integrator output) reading, each representing a time average over .604 seconds. Data were transmitted giving the instrument temperature, and the reading of a clock located at the receiving earth tracking station which gave the elapsed time in milliseconds from January 1 of the current year. These data tapes were sent via air mail to the University of Maryland, where further data processing was to be done.

Considerable difficulty was at first experienced in reading the tapes on Maryland's Univac 1108 computer system, so it became necessary to check the data for proper time increment between records and stable experiment status, tide, and temperature readings.

Each data word was supplied in ten bit format, representing logarithmically the entire voltage range of each measurement. The seismic data were analyzed by filtering and Fourier analysis to detect significant movement of the sensor. The response curve to a typical narrow band filter used to separate the resonant frequency of the sensor from background noise is shown in Figure 7. Free modes data also were Fourier analyzed with the resultant power spectral density records being added together to improve the probability of detecting persistent periodicities in the free mode signal.

By early 1974 the new PDP 11 system was operating, and the quality of the packed data tapes had improved to a point that much of the error checking was no longer necessary. The seismic data were extracted and written on nine track tapes in 2048 sixteen bit word records each containing time information, and the free modes data were written onto disk for later processing. Additional programs were written to: a) read a record of seismic data, b) plot a power spectral density over the 2048 points, c) filter the data with any desired bandwith. Capabilities existed to scan several records of data for signs of seismic activity, "freeze" a particular record on the screen, determine the location and amplitude of the largest or any selected spectral peak, change the gain or filtering limits of the display, or to see a particular time series of data in slow motion.

DUMP OF TAPE APO-17

D-31943

INPUT TAPE APO-17 ON MT3
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CONYG BLKSEQ ARGONNE 0 1 062178

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(96)	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000	000000000000
(144)	000000000000	000000000000	000000000000	000000000000				

170807

FILE 1 RECORD 2259 LENGTH 17648 BYTES 163928

A SDFF * 1/2 THR LEVEL: 0

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               RECS.        INPUT        SIZE       PERM   ZERO B    SHORT   UNDEF.   #RECS.   TOTAL#
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EOJ        DUMP STOPPED AFTER FILE    32          # OF PERMANENT READ ERRORS  0

START TIME 10/23/80   09:14:48         STOP TIME 10/23/80   09:15:33
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